KORSMO & NEININGER

Experiments upon the

Discharge of Water through

Small Fire Hose and Nozzles

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EXPERIMENTS UPON THE DISCHARGE OF WATER THROUGH SMALL FIRE HOSE AND NOZZLES

BY

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AND
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This is to certify that the thesis prepared in the Department of Theoretical and Applied Mechanics by EDWARD OSWALD KORSMO and ALONZO BEDA NEININGER entitled Experiments Upon The Discharge of Water Through Small Fire Hose and Nozzles is approved by me as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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I.

INTRODUCTION.

The efficiency of small fire-hose and nozzles found on the market today is a question of interest to owners of large buildings. New building laws are requiring more adequate fire protection, and to meet these demands manufacturers of fire supplies have placed upon the market various types of hose and nozzle, from which the purchaser is left to choose some particular type, knowing but little as to its fitness.

Extensive tests have been made upon large hose and nozzles and valuable information obtained. It is not known, however, whether the results of these tests can be used to determine the performance of smaller fire equipment, with any degree of accuracy.

The purpose of this thesis is to test 1 1/2-in. hose and nozzles for the discharge of nozzles of various sizes of openings, to study the character of the streams, and to determine the losses due to friction in different kinds of hose. In the following pages, the tests conducted will be considered under the following heads, 1. available data, 2. apparatus and methods of conducting tests, 3. discussion of data and results, 4. conclusions, 5. tables and curves.

II.

AVAILABLE DATA.

The experiments of John R. Freeman on the hydraulics of fire streams furnish the best source of information on hose and nozzles. The tests which he conducted, however, cover the subject of 2 1/2-in. hose and nozzles and do not consider the smaller sizes. Furthermore, Mr. Freeman's nozzles were all smoothly finished and not rough like those herein tested. For this reason the results he obtained are not directly comparable to these tests. However, they give a fair source for comparison.

Among the subjects which Mr. Freeman investigated were:- (1) coefficient of discharge for nozzles of various forms, (2) loss of pressure by friction in hose with interior surfaces of various degrees of smoothness, (3) effect of curves in line of fire hose upon loss of pressure, (4) height and distance reached by jets of water under various pressures.

As a result of his investigations Mr. Freeman concludes, (1) that the average value of the coefficient of discharge for smooth cone nozzles is about 0.970, (2) that the loss of pressure due to friction in hose follows the common theory, being proportional to the square of the discharge closely enough for all practical purposes; the loss in head for unlined linen hose is about twice as much as the loss in rubber lined hose, the value for unlined linen being about 0.46, and that of rubber lined cotton, about 0.25, (3) the loss due to bends is approximately one percent of the total loss for curves of 2-ft. radius and 90 degrees of arc, (4) that the maximum distance that a stream may be

thrown occurs when the nozzle is inclined at an angle of about 32 degrees with the horizontal.

A complete account of Mr. Freeman's experiments is given in Volume XXI of the Transactions of the American Society of Civil Engineers.

III.

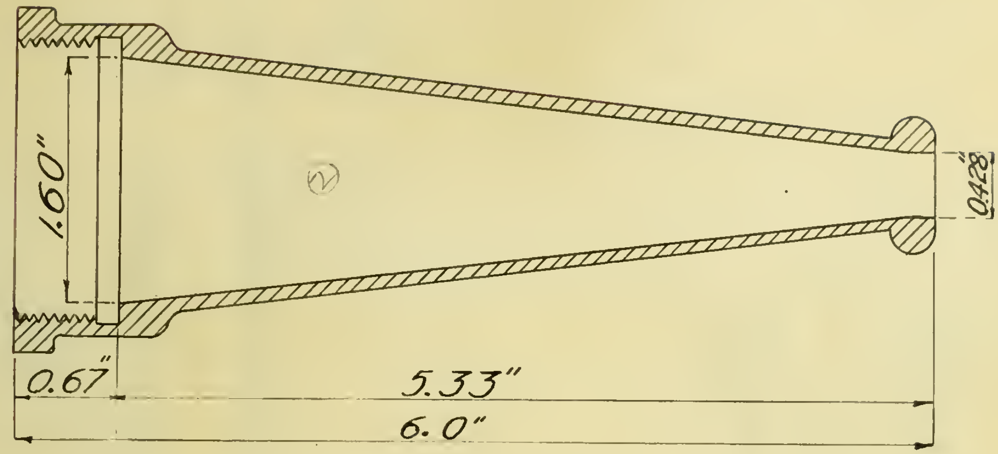
APPARATUS AND METHOD OF CONDUCTING TESTS.

Two kinds of hose were used in these tests. These hose were selected at random from reels in the various buildings of the University of Illinois, and had been in service for some time. Both kinds were of the stock size known as 1 1/2-in. hose. The first hose tested was rubber-lined cotton with an internal diameter of 1.52 inches. The second hose tested was unlined linen with an internal diameter of 1.56 inches.

Three nozzles were tested. All the nozzles were taken from the stock on hand at the University and were used on the 1 1/2-in. hose. The first nozzle tested had an opening 0.428-in. in diameter. The inside of the nozzle was not finished, being rough just as it had come from the mold. A drill had been run through the end of the nozzle to make the opening smooth, round, and of a uniform size for a short length at the tip. This nozzle is shown in Fig. 1, and will be referred to hereafter as nozzle A. The second nozzle tested was the same as nozzle A, except that it was bored out to remove the roughness and the opening made a uniform size for a length of 1/2 in. with a 1/2-in. reamer. This nozzle is shown in Fig. 2 and will be referred to hereafter as nozzle B. The third nozzle tested had an opening of 0.512 in. in diameter. The inside was unfinished as in the case of nozzle A. This last nozzle is shown in Fig. 3, and will be referred to hereafter as nozzle C.

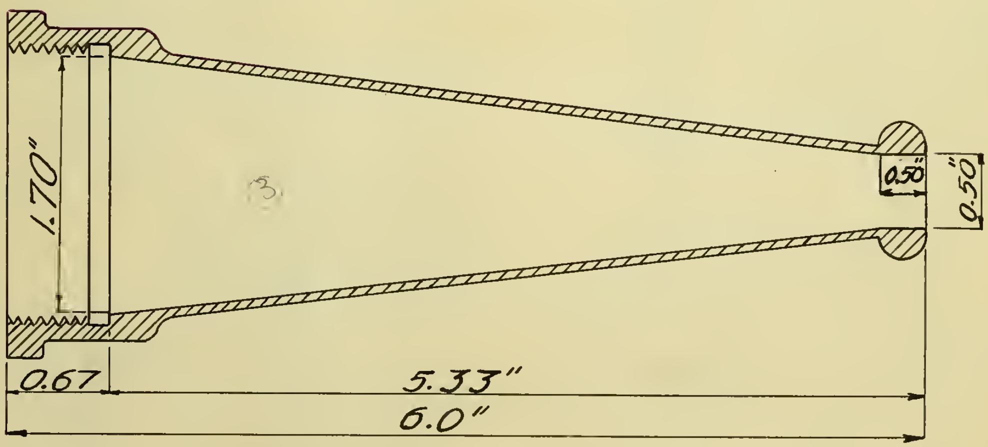
The pressure at the base of the nozzle was measured with Bourdon gauges. In general, one gauge was used for small pressures and another for higher pressures. Both gauges were calibrated with a Crosby Gauge

FIG. I



NOZZLE "A"

FIG. 2



NOZZLE "B"

FIG. 3

NOZZLE "C"

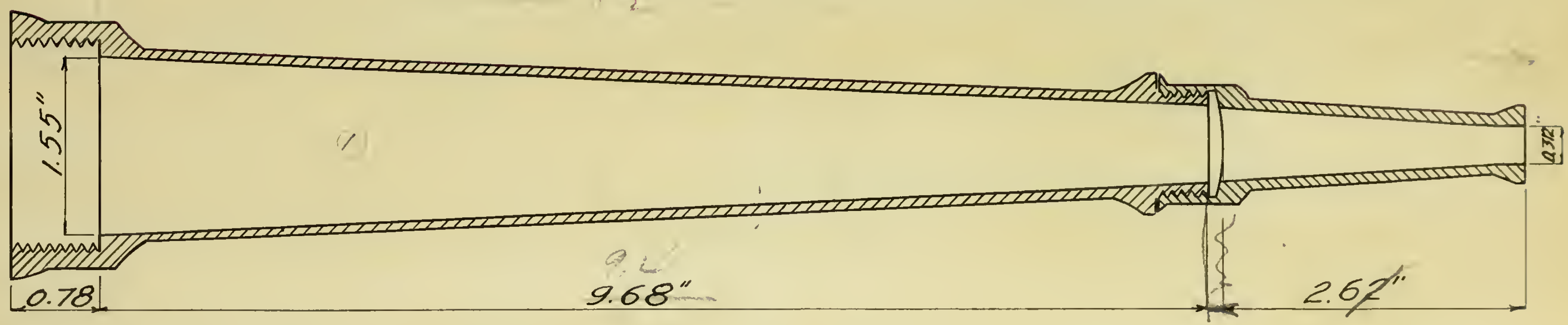
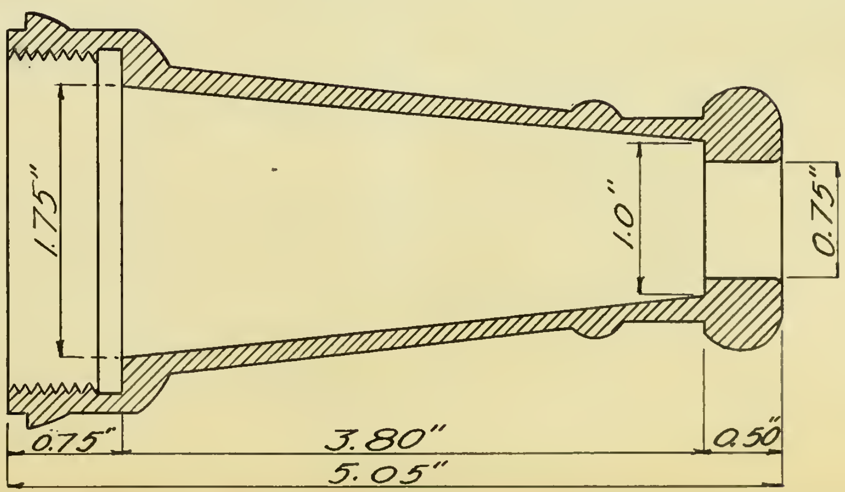


FIG. 4

NOZZLE "D"



Tester. The first gauge was graduated to read pressures up to 75 lb. per sq. in. This gauge and its connections are shown in Fig. 5 and will be referred to hereafter as gauge G-1. The connections shown are ordinary 1/4-in. pipe fittings consisting of two nipples (a,a), a tee (b), a drain cock (c), and a cut-off valve (d). The second gauge was graduated to read pressures up to 100 lb. per sq. in. This gauge will be referred to hereafter as gauge G-2. The connections were the same as for gauge G-1.

The average pressure at a section of the stream was obtained by means of piezometer couplings. A sketch of one of these couplings is shown in Fig. 6. The pressure of the stream is transmitted to the pressure chamber (O) through four 0.10-in. holes A, B, C, D, equally spaced around the circumference. A 1/4-in. nipple connected the pressure chamber to a small rubber tube leading to the pressure gauge.

A hood, which is shown in Fig. 7, was set up 6-ft. from the nozzle to deflect the stream into a galvanized iron tank, resting on an ordinary platform scale.

The loss of head in the hose due to friction was determined with a differential mercury gauge, graduated to read directly in feet of water, the corresponding discharge being obtained by means of a calibrated nozzle. The nozzle used was a smooth finished ring nozzle with an opening 0.75-in. in diameter. This nozzle is shown in Fig. 4 and will be referred to hereafter as nozzle D. A hose length of 100-ft. was used in the tests, the lost head being measured in the last 50-ft, the first 50-ft. being used to steady the flow. It was thought that a sharp bend and a valve at the inlet would make the pressure too irregular to place a piezometer coupling at that point. The general arrangement of the

FIG. 5

PRESSURE GAUGE & CONNECTIONS

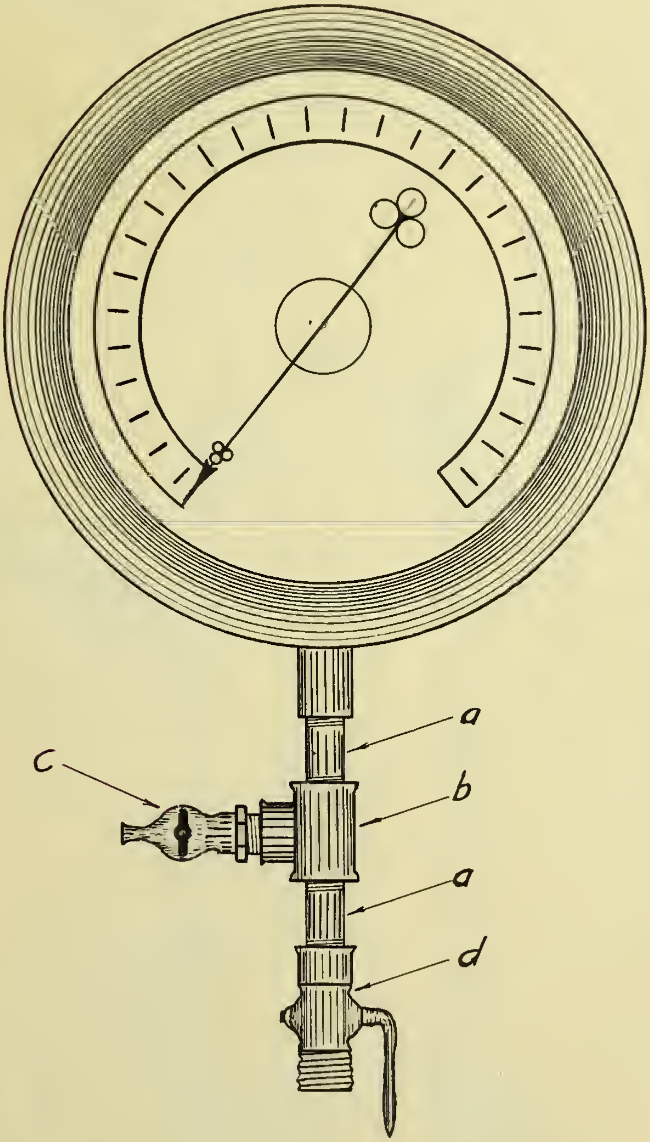
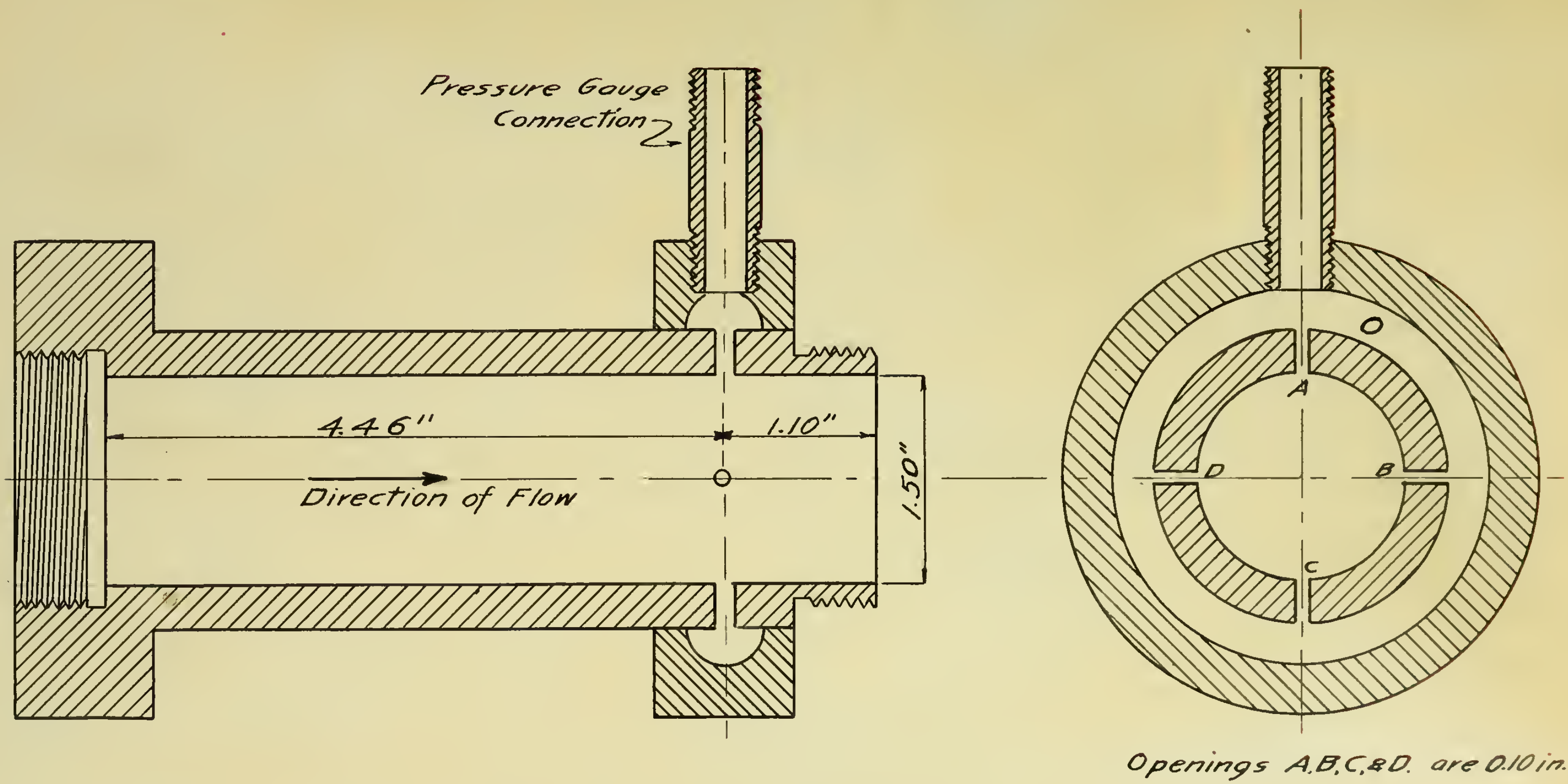


FIG. 6



PIEZOMETER COUPLING

apparatus is shown in Fig. 7.

The determination of the height and the distance the streams could be thrown with various pressures at the base of the nozzle required no additional apparatus other than a transit for measuring vertical angles. Fig. 8 shows a photograph of the apparatus.

The water used in these experiments was drawn from the University mains, the pressure being supplied by the fire pump. Whenever it was necessary, the pump was called upon to furnish fire pressures.

CALIBRATION of NOZZLES: A fifty foot length of rubber-lined cotton hose was connected to a fire plug in the Hydraulics Laboratory and arranged so as to have no sharp curves. The fifteen feet adjoining the nozzle was straight and horizontal. A piezometer coupling, Fig. 6, was connected between the hose and the nozzle to be tested. The coupling and nozzle were also horizontal. The pressure gauge for reading pressures at the base of the nozzle was hung on a framework, the center of the pressure gauge being at the same elevation as the center of the piezometer coupling. The water was defected with a hood into a measuring tank where the rate of discharge was determined. This was accomplished by observing with a stop watch the time required to discharge either 300 lb. or 500 lb., depending upon the rate of discharge. The time was read to one-fifth of a second. The rate of discharge for nozzles A, B, and C was observed for pressures ranging from 12 lb. per sq. in. to 85 lb. per sq. in., and from 5.0 lb. per sq. in. to 21.0 lb. per sq. in. nozzle D. One or more check readings were taken for each head. In every case the drain cock was opened before taking pressure gauge readings in order to remove the air and prevent any errors from this source. The pressure gauge was also rapped lightly at every reading to prevent any

FIG. 7

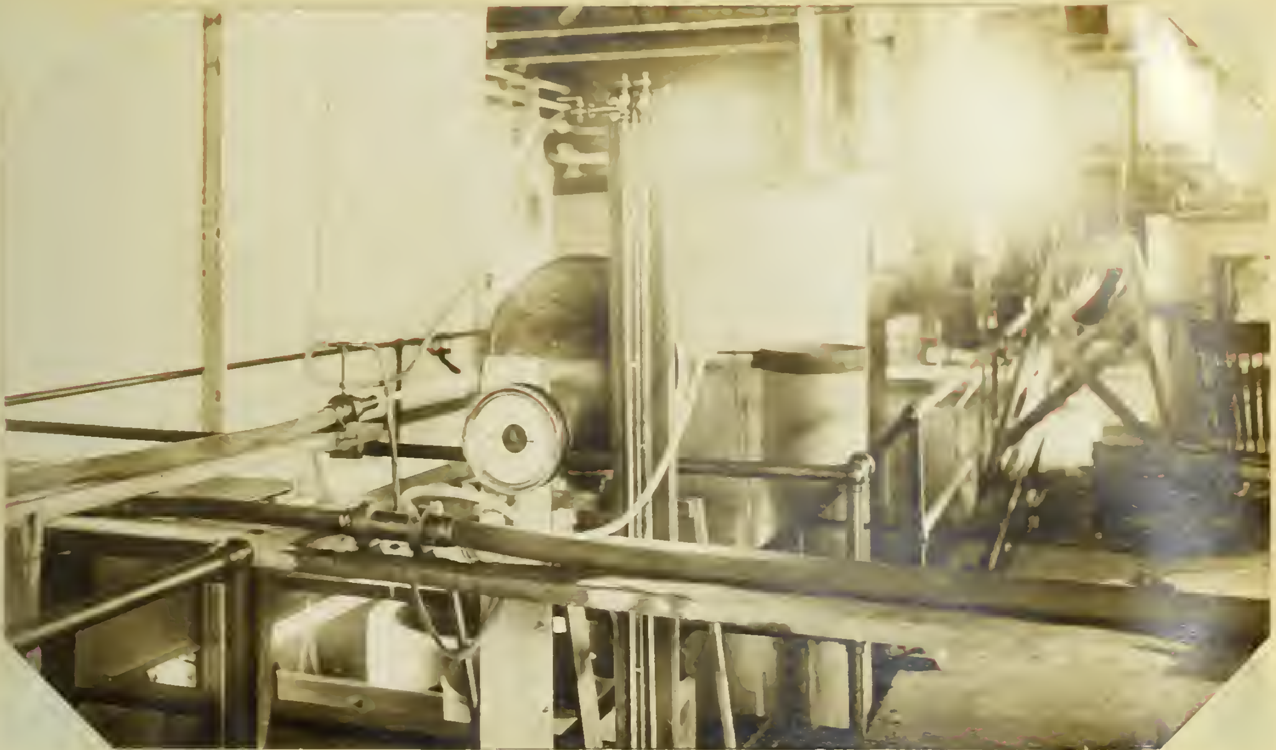


FIG. 8

error due to the inertia of the pointer.

FRICTION IN HOSE: Lack of room made it impossible to lay the 100-ft. of hose in the tests for friction in hose in a straight line. Instead, the hose was laid out with as easy curves as possible, with the first and second piezometer couplings close together. The piezometer couplings were on the same elevation as the nozzle and were connected so as to measure the loss of head in the 50-ft. length of hose next to the nozzle. Each piezometer was connected with a rubber tube to a differential mercury gauge thus obtaining directly the head lost in the hose. The discharge through the hose was measured with nozzle D, which had been previously calibrated. A large nozzle was used in order that the work might be carried on with low pressures and still have a good range of velocities. This necessitated reading the pressure at the base of the nozzle with a pressure gauge. In order to have two connections a tee connection was made with the pressure chamber. One connection lead to the mercury gauge and the other to the pressure gauge. Again, care was taken to remove any air in the connecting lines leading to the pressure gauge, and also any error due to the inertia of the pointer on the pressure gauge. Readings were taken for velocities ranging from 4.0 ft. per sec. to 7.5 ft. per sec. and checked in every case.

HEIGHT, DISTANCE, AND QUALITY OF FIRE STREAMS: This part of the work was carried on out of doors. A connection was made to a hydrant on the University water mains, with a 50-ft. length of hose leading to the nozzle. The tests were not gone into as far as had been intended because of lack of time and proper conditions for making tests. The day the tests were made a wind was blowing which had considerable effect upon the streams. In obtaining the distance the stream could be thrown,

the nozzle was set at an angle of about 50° with the horizontal since this seemed to give the maximum range. In getting the distances under five different heads for nozzles A, B, and C, stakes were driven along the line of the stream every 10-ft. and the distance between a stake and the end of the stream was estimated. The nozzle pressure was obtained with a pressure gauge. In getting the height of the streams the nozzle was set so the stream was almost vertical. The height of the stream was obtained by setting up a transit 40-ft. from the nozzle and at right angles to the stream, and reading the vertical angle. Readings were taken with nozzles A, B, and C for two different pressures.

IV.

DISCUSSION OF DATA AND RESULTS.

The data shown in the tables at the end of this thesis give the results of all the tests that were made. In every case the weight of one cubic foot of water was taken as 62.5 lb. and the acceleration due to gravity, g, as 32.2 ft. per sec. per sec. The corrected heads were taken from the calibration curves for pressure gauges G-1 and G-2, shown in Plate 1 and Plate 2. Tables 1,2,and 3 were compiled from the data obtained in calibrating nozzles A, B, and C. These data are plotted in Plates 3 and 4. The theoretical discharge was calculated from the formula $Q = F\sqrt{2gh}$ where, Q, is the discharge in cu. ft. per sec., F, the area of the nozzle opening in sq. ft., and, h, the head at the base of the nozzle in ft. of water. The coefficient of discharge, C_d was obtained by dividing the actual discharge by the theoretical discharge. Table 4 needs no discussion other than to state that its only use was to obtain the discharge in the tests on friction in hose. For this purpose it was only necessary to obtain the discharge for the gauge readings used in the friction tests.

Table 5 gives the data on friction in hose, and the results are plotted in Plate 5 and Plate 6. The lost head as obtained from the differential mercury gauge depends on the value taken for the specific gravity of mercury. In these tests the value used was 13.6. In calculating the friction factor, f, the formula $H = f\frac{l}{d}\frac{v^2}{2g}$ or $f = \frac{2dg}{l}\frac{H}{v^2}$ was used, in which, H, is the lost head in feet of water, d, the diameter of the hose in feet, l, the length of the hose in feet, and, v, the

velocity of the flow in ft. per sec. The velocity was obtained by dividing the discharge in cu. ft. per sec. as observed in calibrating the nozzle D, by the area of the hose in sq. ft. The area of the hose was obtained by cutting off a piece of the hose and calculating the area from a measurement of the inside circumference.

Table 6 gives, (1) the maximum distance the stream through nozzles A, B, and C could be thrown, (2) the distance the stream was effective, (3) the maximum height the stream would carry, and (4) the effective height the stream would carry under various heads. These data are plotted in Plates 7 and 8 . In determing what should be considered the point where the stream was effective the section was taken where practically all the water would strike an area 18-in. in diameter.

Table 7 gives a summary of all data taken. All the values shown were taken from the curves plotted from this data. Where such data was not available from actual experiment the values used were taken from a continuation of these curves.

Turning to a consideration of theresults, it will be noted that no mention is made of errors. One of the errors is that due to velocity of approach. The maximum error due to this amounted to but 0.3 percent and was neglected. In regard to the reading of pressures with a Bourdon gauge it is true that this type of gauge is not as sensitive as a mercury gauge, and errors in pressures may exist. However, from the regularity of the points on the discharge curves, Plate 3 and coefficient of discharge curve Plate 4, it is evident that these errors must be small. There may be other sources of error besides the two mentioned, but in all cases they are small. To have eliminated them would have necessitated more sensitive apparatus, more time, and an expenditure

of money that was not warranted.

The principle point to be noticed in the tables is the difference in the nozzles, and the difference in the head lost in the two hose tested. Nozzles A, B, and C are of different sizes and hence the only comparison as regards discharge lies in the coefficients of discharge. There seems to be very little difference in any case in so far as the numerical value of the coefficient is concerned, but it will be observed by looking at the data, Tables 1, 2, and 3, or still better by looking at the curves Plate 4 that in nozzles A and C the coefficients decrease more rapidly with an increase in head than nozzle B does. This is as might be expected since nozzles A and C have rough interiors and nozzle B a smooth interior, and hence have a greater loss of head due to friction. The real difference in the nozzles, however, lies in the quality of the stream they discharge. This is not very clearly shown either in the photographs, Fig. 9, 10, and 11, or in the data Table 6, but to the observers the difference was very marked. A wind was blowing at the time of the tests, making it impossible to get the best results, and lack of time prevented their being repeated under better conditions. In spite of the fact that photographs of the streams do not show up very well, a careful study of them will bring out the points of interest. Nozzle C gave a stream which began to break up as soon as it left the nozzle, and was easily diverted and broken up by the wind (see Fig. 9). Nozzle A gave a stream better than nozzle C, but it too began to break up at the nozzle and was easily diverted by the wind (see Fig. 10). Nozzle B, on the contrary, gave a much better stream than either nozzle A or nozzle C. It carried farther and higher than the other two and although the whole stream was effective for a distance not much greater than that of nozzle A and C, the greater part of the

FIG. 9

FIG. 10

FIG. 11

stream was effective for more than fifty feet. (See Fig. 11). It must be remembered, however, in comparing these nozzles that nozzle B was larger than either nozzle A or C and this would account in part for the lesser effect of the wind on its discharge. The length of the cylindrical tip on the nozzle also affects the quality of the stream. When nozzle B was being finished on the inside an opening of 0.469 inches in diameter was tried, but it did not give a solid stream. It was then drilled to 0.500 in. in diameter, thereby giving a longer cylindrical tip. This gave a stream which would carry much farther before breaking up.

The data on friction in hose shows that the unlined linen hose gives a loss of head nearly twice as large as the rubber lined cotton hose. The friction factor for 1 1/2-in. smooth cast-iron pipe as determined from Darcy's formula $f = .0199 + \frac{.00166}{d}$ is .0528. This, it will be noted, agrees closely with the friction factor for the rubber lined hose. In general the friction factor for both hose varyapproximately as the square of the discharge. The curves show that there is considerable variation in the friction factors in the hose. This is especially true in the unlined linen hose and may be accounted for in that the friction factor varies inversely as the fifth power of the diameter, thereby causing considerable error with a small variation in the size of the hose.

V.

CONCLUSIONS.

The conclusions to be drawn from these tests must be necessarily based on the question of what is the purpose of small hose and nozzle. If the purpose of small hose and nozzle is merely to extinguish a small blaze nothing has been brought out in these tests which would tend to show that nozzles such as nozzles A and C are not satisfactory. If, on the contrary, it be considered that small hose and nozzle should not only be efficient in extinguishing small blazes, but should also be of some use in fighting a more serious fire, then nozzles A and C are not efficient. This is particularly true of nozzle C, since the discharge is so small as to make it practically useless.

In the two nozzles A and C some of the difficulty is due to the roughness of the interior of the nozzle. This roughness was not only peculiar to the nozzles tested, but was also in all of the nozzles found about the University. In some cases projections as high as 1/8-in. were found.

Another difficulty with nozzles A and C lies in the fact that the opening is not as smooth as it should be. An endeavor was no doubt made to accomplish this end by the insertion of a drill, but the results obtained were far from satisfactory. The openings should be bored or reamed. In general, it may be said that enough care is not exercised by manufacturers of fire equipment in making small nozzles.

The experiments dealing with friction in hose show clearly the advantage of rubber-lined cotton hose over unlined linen hose, the loss due to friction being twice as great in the latter as in the former.

This agrees closely with the results obtained by Mr. Freeman in his experiments on 2 1/2 in. hose. For the rubber lined hose and the unlined linen hose the friction factor obtained by Mr. Freeman for 2 1/2 in. hose is approximately four-fifths of the friction factor herein obtained for 1 1/2-in. hose. It would seem, therefore, that, neglecting the element of cost and deterioration, the rubber-lined hose is far superior to the unlined linen hose.

VI.

TABLES AND CURVES.

TABLE I

CALIBRATION OF NOZZLE "A"

DIAMETER = 0.428 in.

DATA & RESULTS

Area = 0.0009915 sq. ft.

Gauge Used	No. of Trials	Head			Time	Total Discharge	Discharge		C_D
		Gauge	Corrected				Actual	Theo.	
		ft.	lb. sq. in.	ft.	Sec.	lb.	Cu. ft. sec.	Cu. ft. sec.	
G-1	2	30.0	11.78	27.2	194.0	500	0.0412	0.0419	.984
"	"	40.0	16.25	37.6	163.4	"	0.0489	0.0493	.992
"	"	50.0	20.78	48.0	145.6	"	0.0550	0.0556	.990
"	"	60.0	25.30	58.5	133.4	"	0.0599	0.0614	.976
G-2	"	70.0	27.91	64.5	76.2	300	0.0629	0.0645	.967
"	4	80.0	32.19	74.4	71.4	"	0.0670	0.0693	.967
"	3	90.0	36.79	85.0	67.2	"	0.0711	0.0740	.961
"	"	100.0	41.10	95.0	63.6	"	0.0754	0.0783	.962
"	"	110.0	45.70	105.6	60.8	"	0.0789	0.0824	.958
"	2	120.0	50.20	116.0	56.8	"	0.0841	0.0865	.970
"	"	130.0	54.51	126.1	54.8	"	0.0875	0.0902	.970
"	"	140.0	58.90	136.1	53.4	"	0.0901	0.0937	.962
"	3	150.0	63.10	146.0	52.2	"	0.0920	0.0970	.949
"	4	160.0	67.60	156.2	50.6	"	0.0954	0.1004	.948
"	"	170.0	71.95	166.1	48.6	"	0.0982	0.1035	.948
"	"	180.0	76.10	176.0	48.0	"	0.1010	0.1066	.948
"	"	190.0	80.60	186.1	46.2	"	0.1039	0.1095	.948
"	"	200.0	84.80	196.0	74.8	500	0.1069	0.1125	.948

TABLE 2

CALIBRATION OF NOZZLE "B"

DIAMETER = 0.50 in.

DATA & RESULTS

Area = 0.001362 sq. ft.

Gauge Used	No. of Trials	Head			Time	Total Discharge	Discharge		C_D
		Gauge	Corrected				Actual	Theo.	
		ft.	lb. sq. in.	ft.	sec.	lb.	cu. ft. sec.	cu. ft. sec.	
G-1	2	30	11.78	27.2	143.6	500	0.0556	0.0571	.974
"	"	40	16.25	37.6	121.4	"	0.0658	0.0672	.979
"	"	50	20.78	48.0	108.0	"	0.0739	0.0757	.976
"	"	60	25.30	58.5	97.8	"	0.0818	0.0836	.977
G-2	"	60	23.28	53.8	102.0	"	0.0784	0.0801	.979
"	"	70	27.91	64.5	91.6	"	0.0873	0.0880	.991
"	3	80	32.19	74.4	87.0	"	0.0920	0.0945	.973
"	"	90	36.79	85.0	82.0	"	0.0976	0.0995	.980
"	"	100	41.10	95.0	76.4	"	0.1045	0.1068	.980
"	"	110	45.70	105.6	72.4	"	0.1106	0.1121	.986
"	"	120	50.20	116.0	69.0	"	0.1152	0.1179	.979
"	"	130	54.51	126.1	66.2	"	0.1209	0.1229	.984
"	4	140	58.90	136.1	64.8	"	0.1235	0.1278	.968
"	"	150	63.10	146.0	62.6	"	0.1277	0.1321	.965
"	"	160	67.60	156.2	60.6	"	0.1320	0.1369	.965
"	"	170	71.95	166.1	58.8	"	0.1360	0.1410	.965
"	"	184	74.70	180.0	56.0	"	0.1429	0.1465	.975

TABLE 3

CALIBRATION OF NOZZLE "C"

DIAMETER = 0.312 in.

DATA & RESULTS

Area = 0.000531 sq. ft.

Gauge Used	No. of Trials	Head: Gauge ft.	Head: Corrected lb. sq. in.	Head: Corrected ft.	Time sec.	Total Discharge lb.	Discharge: Actual Cu. ft. sec.	Discharge: Theo. Cu. ft. sec.	C_D
G-2	2	40	14.11	32.6	204.6	300	0.0235	0.0249	.961
"	"	50	18.70	43.2	179.8	"	0.0267	0.0280	.953
"	"	60	23.28	53.8	161.6	"	0.0297	0.0313	.949
"	"	70	27.91	64.5	147.6	"	0.0325	0.0343	.947
"	"	80	32.19	74.4	136.0	"	0.0353	0.0368	.959
"	"	90	36.79	85.0	129.0	"	0.0372	0.0393	.946
"	"	100	41.10	95.0	122.6	"	0.0391	0.0416	.940
"	"	110	45.70	105.6	115.6	"	0.0415	0.0437	.949
"	"	120	50.20	116.0	109.0	"	0.0440	0.0459	.959
"	"	130	54.51	126.1	105.0	"	0.0457	0.0479	.953
"	"	140	58.90	136.1	102.6	"	0.0467	0.0497	.940
"	"	150	63.10	146.0	98.4	"	0.0488	0.0515	.949
"	"	160	67.60	156.2	94.8	"	0.0506	0.0533	.948
"	"	170	71.95	166.1	91.6	"	0.0513	0.0550	.933
"	"	180	76.10	176.0	89.8	"	0.0535	0.0566	.945

TABLE 4

CALIBRATION OF NOZZLE "D"

DIAMETER = 0.75 in.

DATA & RESULTS

Gauge Used	No. of Trials	Head Gauge ft.	Head Corrected lb.sq.in.	Head Corrected ft.	Time Sec.	Total Discharge lb.	Discharge Cu.ft.sec.
G-1	2	15	5.09	11.79	147.1	500	0.0543
"	3	20	7.49	17.10	70.6	300	0.0679
"	2	25	9.60	22.19	62.6	300	0.0767
"	2	30	11.78	27.24	92.9	500	0.0861
"	3	35	13.99	32.34	86.0	500	0.0930
"	2	40	16.25	37.62	79.7	500	0.1003
"	2	45	18.50	42.80	75.1	500	0.1064
"	2	50	20.78	48.00	71.8	500	0.1112

TABLE 5

FRICTION IN HOSE

Cotton, Rubber Lined Diam. = 1.52 in. Area = 0.01260 sq.ft.

Linen Lined Diam. = 1.56 in. Area = 0.01328 sq.ft.

DATA & RESULTS

Kind of Hose	Head at Base of Nozzle: Gauge ft.	Head at Base of Nozzle: Corrected lb.sq.in	Head at Base of Nozzle: Corrected ft	Discharge cu.ft.sec.	Velocity ft.per.sec.	Lost Head ft.per 100 ft.	Friction Factor
Rubber Lined	15	5.09	11.79	0.0543	4.31	7.40	0.0325
" "	20	7.49	17.10	0.0679	5.38	11.00	0.0310
" "	25	9.60	22.19	0.0767	6.08	14.14	0.0312
" "	30	11.78	27.24	0.0861	6.83	17.22	0.0302
" "	35	13.99	32.34	0.0930	7.38	19.90	0.0298
Linen Lined	15	5.09	11.79	0.0543	4.08	14.64	0.0736
" "	20	7.49	17.10	0.0679	5.11	19.90	0.0638
" "	25	9.60	22.19	0.0767	5.77	24.60	0.0619
" "	30	11.78	27.24	0.0861	6.48	28.80	0.0575
" "	35	13.99	32.34	0.0930	7.00	32.40	0.0553
" "	40	16.25	37.62	0.1003	7.56	37.30	0.0547

TABLE 6

HEIGHT & DISTANCE OF JET

DATA & RESULTS

Gauge G-2

Nozzle Used	Head at Base of Nozzle			Distance Discharged		Height of Stream	
	Gauge	Corrected		Effective	Maximum	Effective	Maximum
	feet	lb. sq. in.	feet	feet	feet	feet	feet
"A"	150	63.10	146.0	20	80		
"	120	50.20	116.0	18	70		
"	90	36.79	85.0	15	60		
"	65	25.50	58.9	12	50		
"	138	57.70	133.3			33	39
"	90	36.79	85.0			29	30
"B"	154	64.50	149.0	35	115		
"	120	50.20	116.0	30	102		
"	90	36.79	85.0	24	86		
"	65	25.50	58.9	18	73		
"	136	56.80	131.5			40	50
"	90	36.79	85.0			39	45
"C"	168	70.90	163.9	28	90		
"	144	60.20	139.0	26	85		
"	120	50.20	116.0	24	75		
"	90	36.79	85.0	20	70		
"	60	23.28	53.8	15	62		
"	180	76.10	176.0			38	50
"	90	36.79	85.0			34	43

TABLE 7-a

SUMMARY OF RESULTS

NOZZLE "A"

Pressure at Base of Nozzle	Discharge	Loss of Head per 100 ft. of Hose		Effective Vert. Ht. of Jet	Effective Hor. Dist. of Jet	Maximum Hor. Dist. of Jet
		Rubber Lined	Unlined Linen			
lb. per sq. in.	gal. per min.	lb. per sq. in.	lb. per sq. in.	ft.	ft.	ft.
20	25	3.2	6.4	23	10	45
30	29	4.5	8.2	27	13	54
40	33	5.6	9.9	30	16	63
50	37	6.9	11.7	32	18	70
60	40	8.1	13.4	33	20	77
70	44	9.4	15.2	34	21	84
80	47	10.7	17.9	35	23	91
90	49	11.8	18.3	36	24	99
100	52	12.9	21.9	37	25	106

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 7-b

SUMMARY OF RESULTS

NOZZLE "B"

Pressure at Base of Nozzle	Discharge	Loss of Head per 100 ft. of Hose		Effective Vert. Ht. of Jet	Effective Hor. Dist. of Jet	Maximum Hor. Dist. of Jet
		Rubber Lined	Unlined Linen			
lb. per sq. in.	gal. per min.	lb. per sq. in.	lb. per sq. in.	ft.	ft.	ft.
20	32	5.3	9.5	35	15	63
30	40	7.9	13.2	38	21	79
40	46	10.5	16.6	39	25	91
50	51	12.7	19.5	40	30	102
60	56	14.9	22.0	40½	33	111
70	61	17.1	24.9	40½	37	119
80	65	19.3	26.9	41	40	127
90	69	21.3	29.2	41½	43	134
100	73	23.4	31.4	42	46	141

TABLE 7-c

SUMMARY OF RESULTS

NOZZLE "C"

Pressure at Base of Nozzle	Discharge	Loss of Head per 100 ft. of Hose		Effective Vert. Ht. of Jet	Effective Hor. Dist. of Jet	Maximum Hor. Dist. of Jet
		Rubber Lined	Unlined Linen			
lb. per. sq. in.	gal. per. min.	lb. per. sq. in.	lb. per. sq. in.	ft.	ft.	ft.
20	12	0.8	2.2	29	13	53
30	15	1.2	3.1	32	18	63
40	17	1.6	3.8	34	21	71
50	19	2.0	4.5	35	24	78
60	21	2.4	5.1	36	26	84
70	23	2.8	5.8	37	28	90
80	24	3.2	6.4	38	29	96
90	26	3.7	6.9	39	30	101
100	28	4.0	7.6	40	31	107

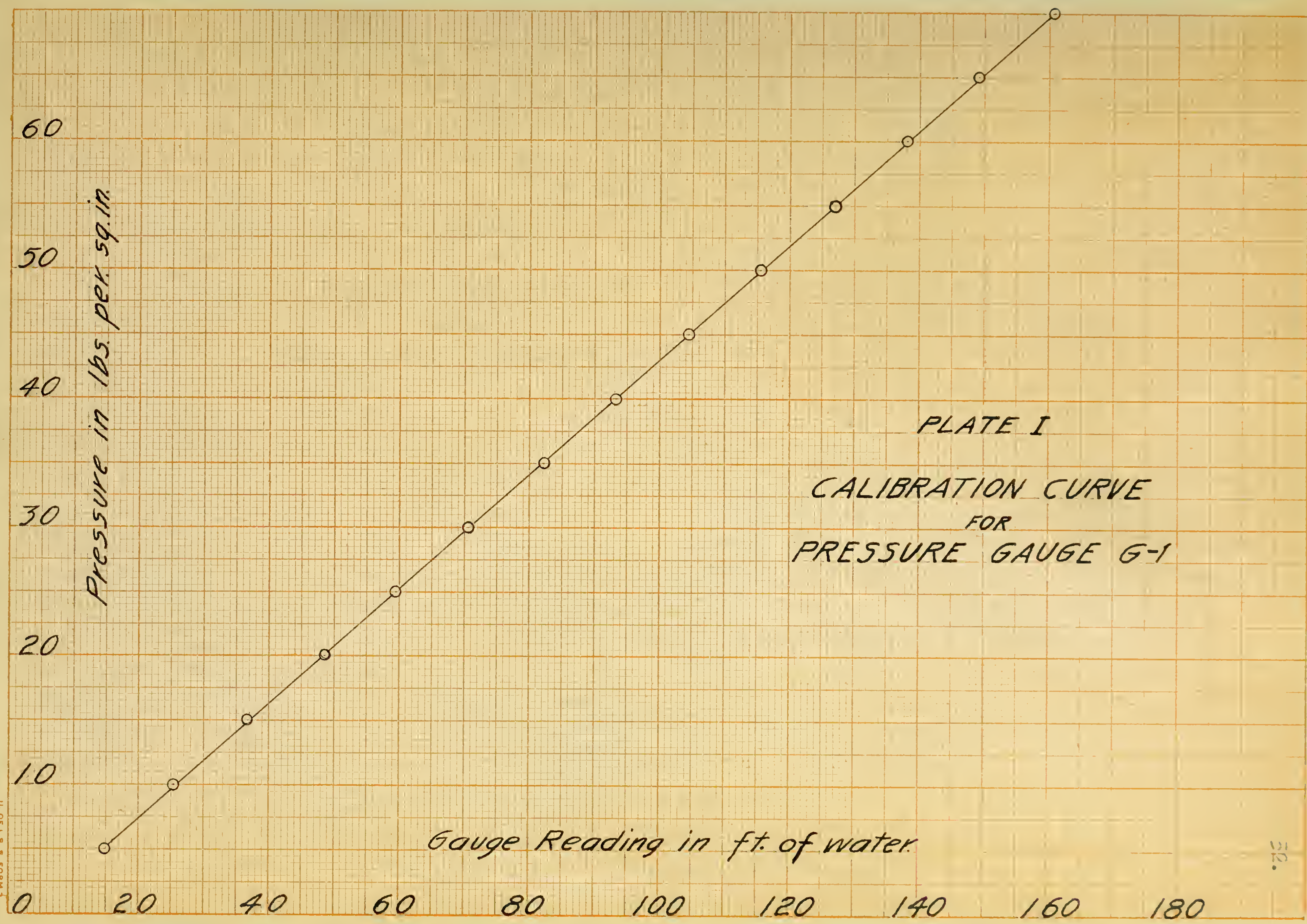


PLATE I
CALIBRATION CURVE
FOR
PRESSURE GAUGE G-1
Pressure in lbs. per sq. in.
Gauge Reading in ft. of water.
0
20
40
60
80
100
120
140
160
180
10
30
50

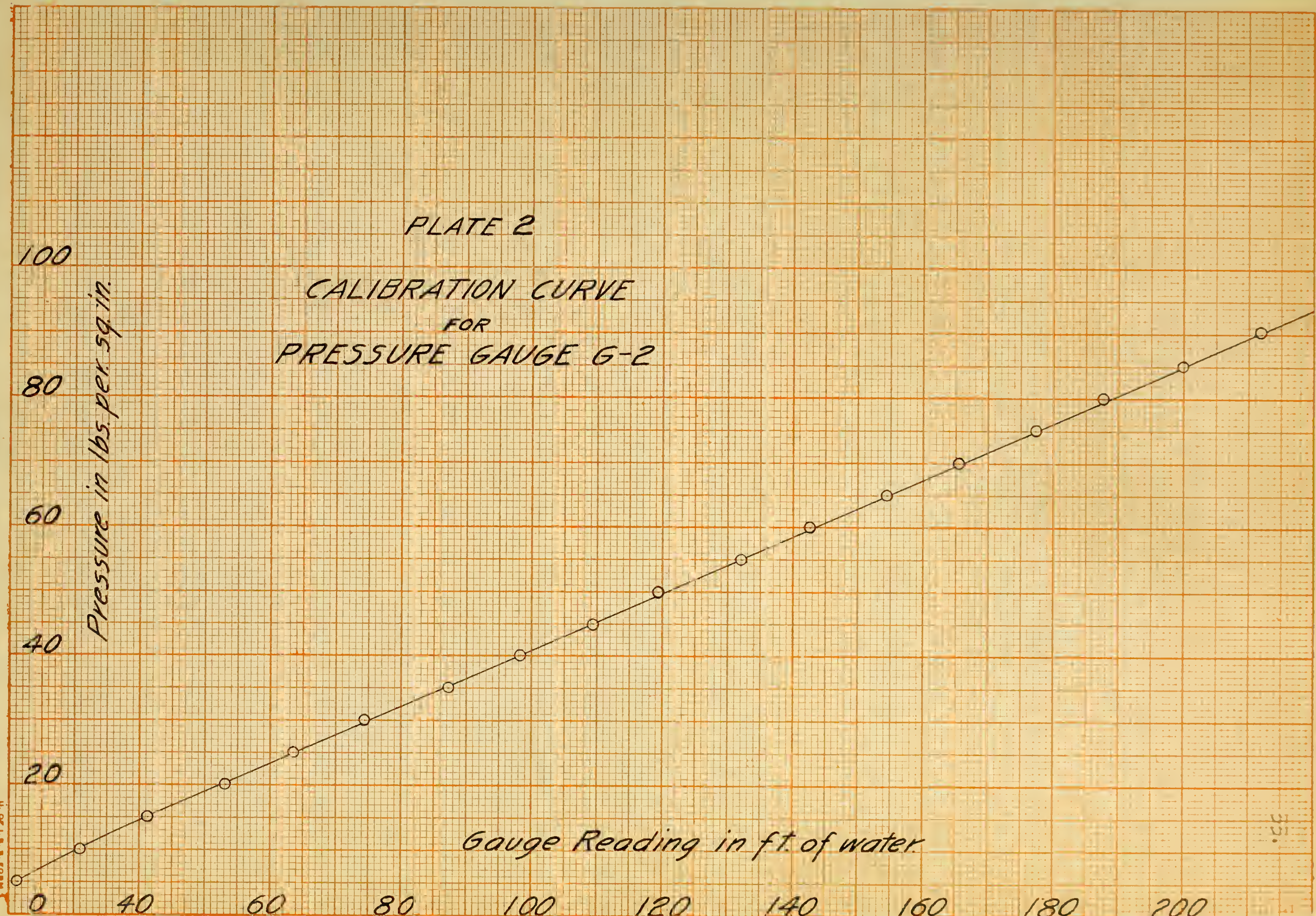


PLATE 2
CALIBRATION CURVE
FOR
PRESSURE GAUGE G-2
Pressure in lbs. per. sq. in.
Gauge Reading in ft. of water.
0
20
40
60
80
100
120
140
160
180
200
U. OF I. E. S. FORM 3
35.

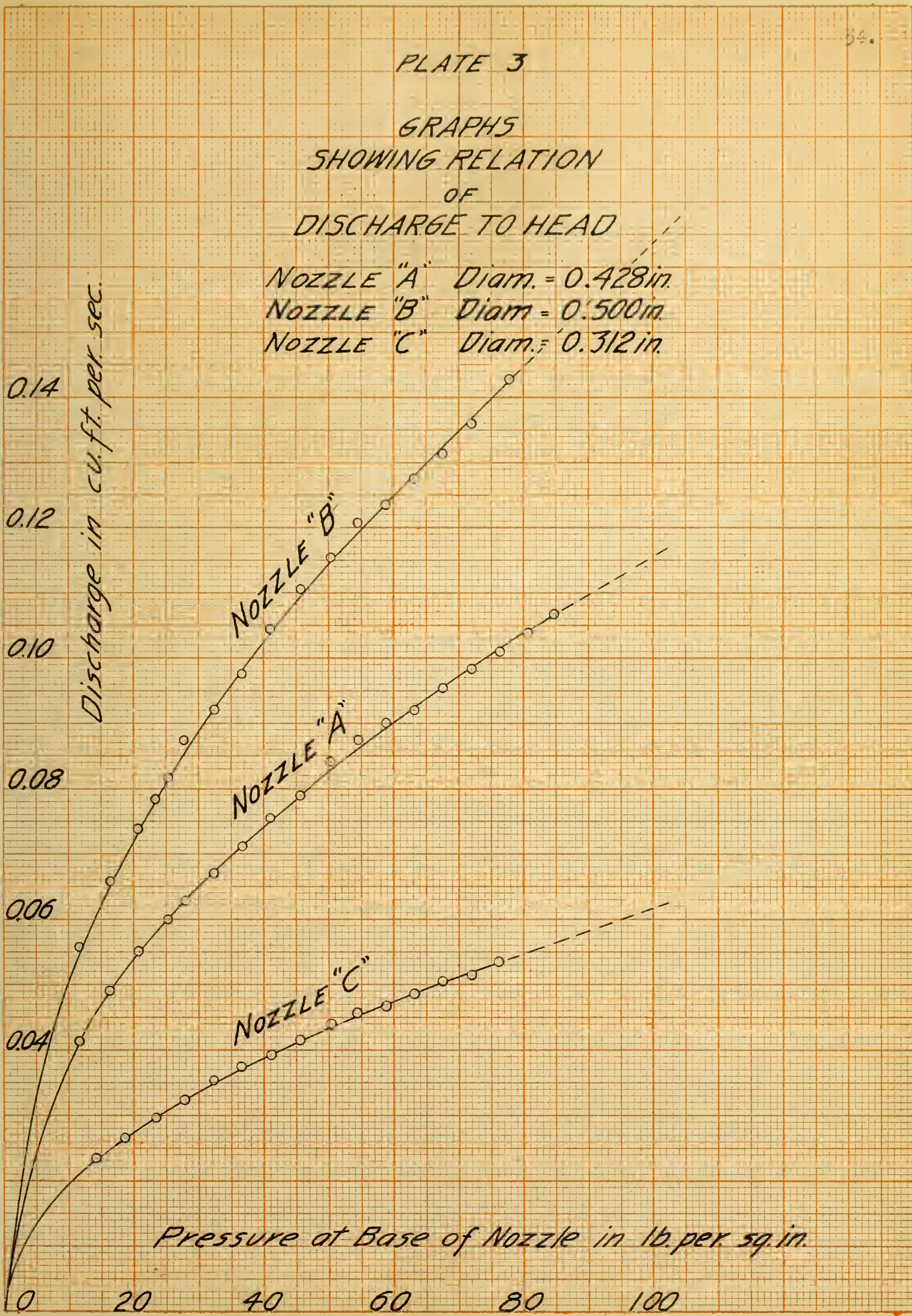


PLATE 3
GRAPHS
SHOWING RELATION
OF
DISCHARGE TO HEAD
NOZZLE "A" Diam. = 0.428 in.
NOZZLE "B" Diam = 0.500 in.
NOZZLE "C" Diam. = 0.312 in.
Discharge in cu. ft. per sec.
0.14
0.12
0.10
0.08
0.06
0.04
Nozzle "B"
Nozzle "A"
Nozzle "C"
Pressure at Base of Nozzle in lb. per sq. in.
0
20
40
60
80
100

PLATE 4

GRAPHS SHOWING RELATION OF COEF. OF DISCHARGE TO HEAD

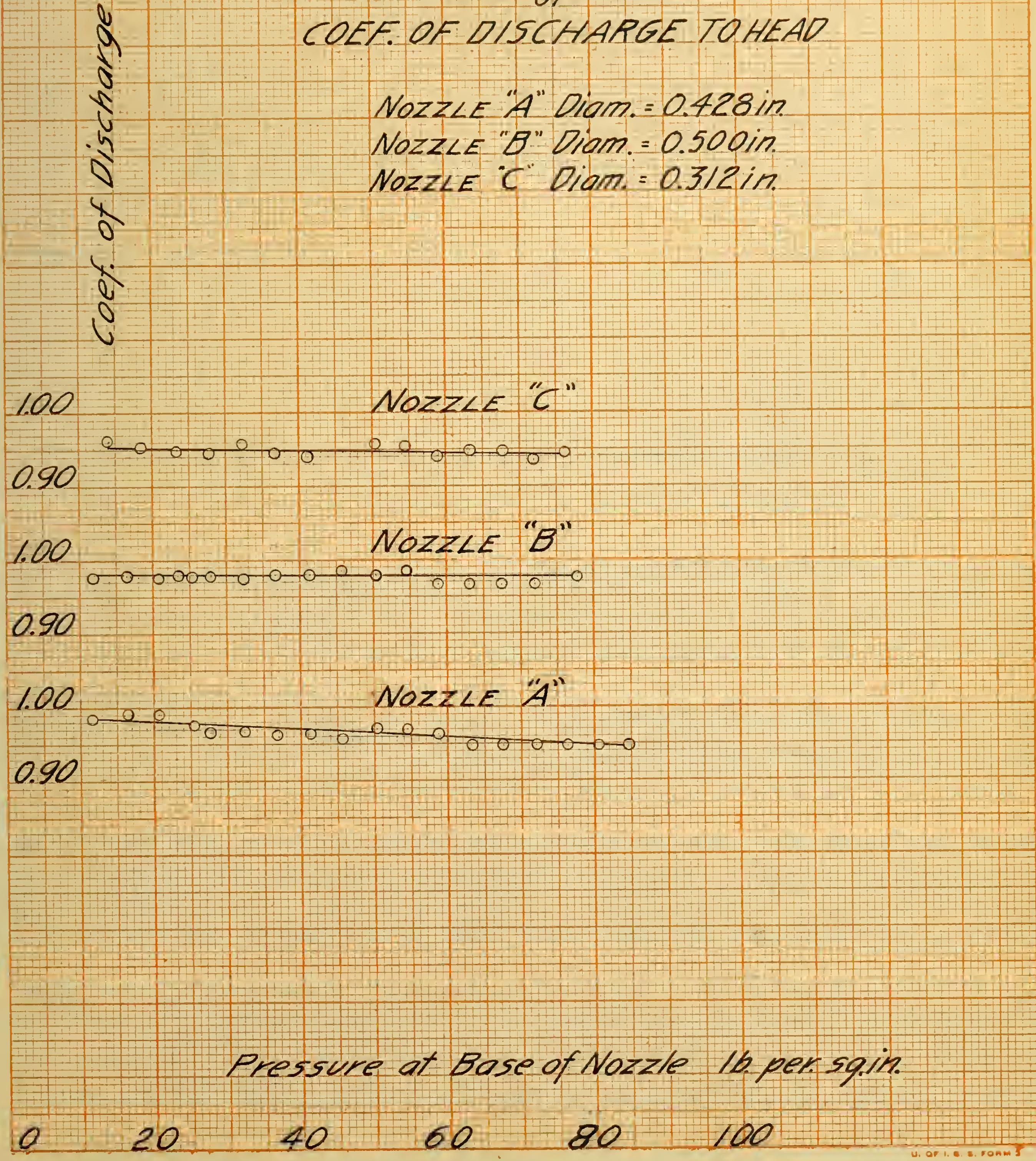


PLATE 5

GRAPHS
SHOWING RELATION
OF
HEAD LOST PER 100 Ft. OF HOSE
TO
VELOCITY IN HOSE

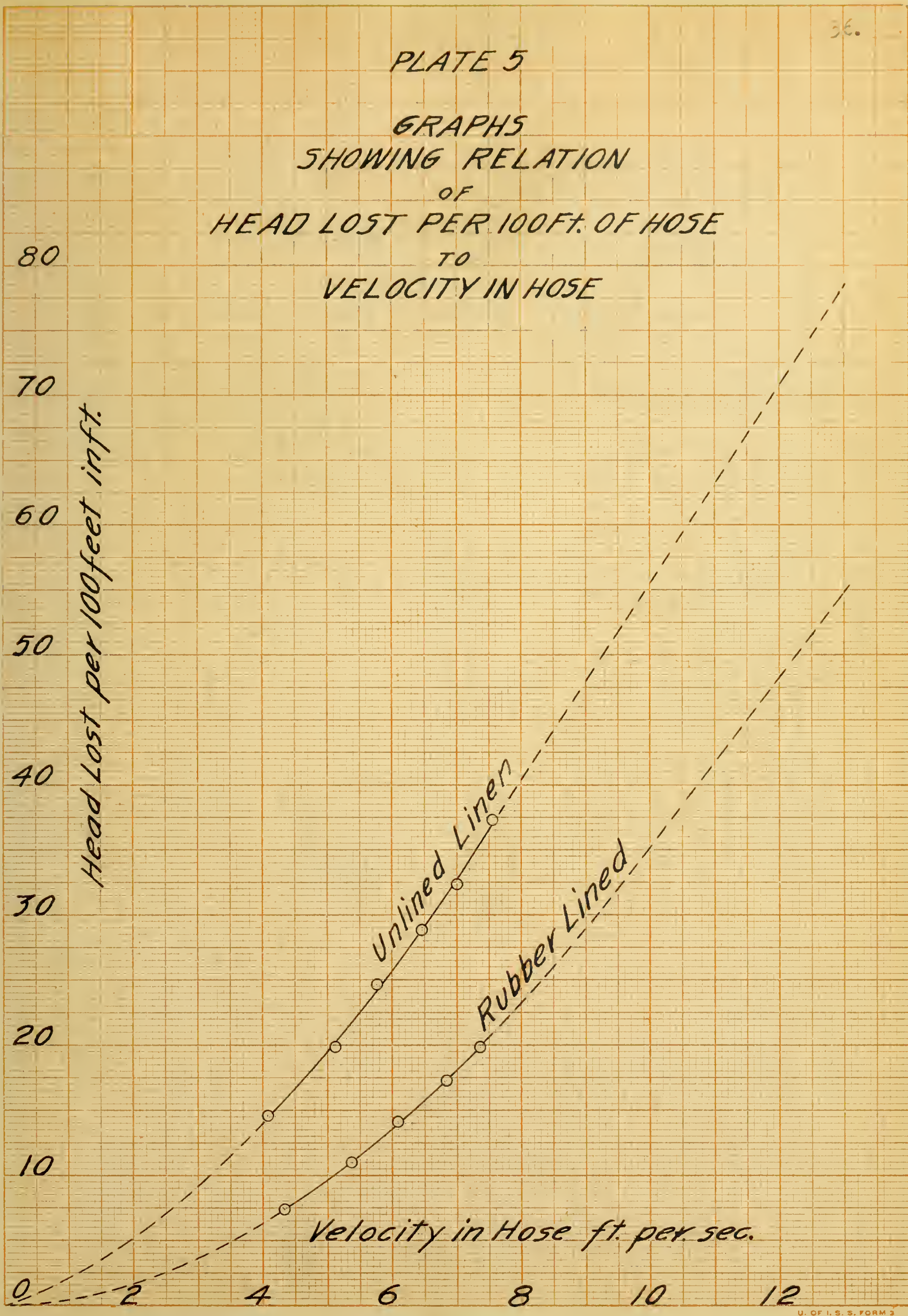
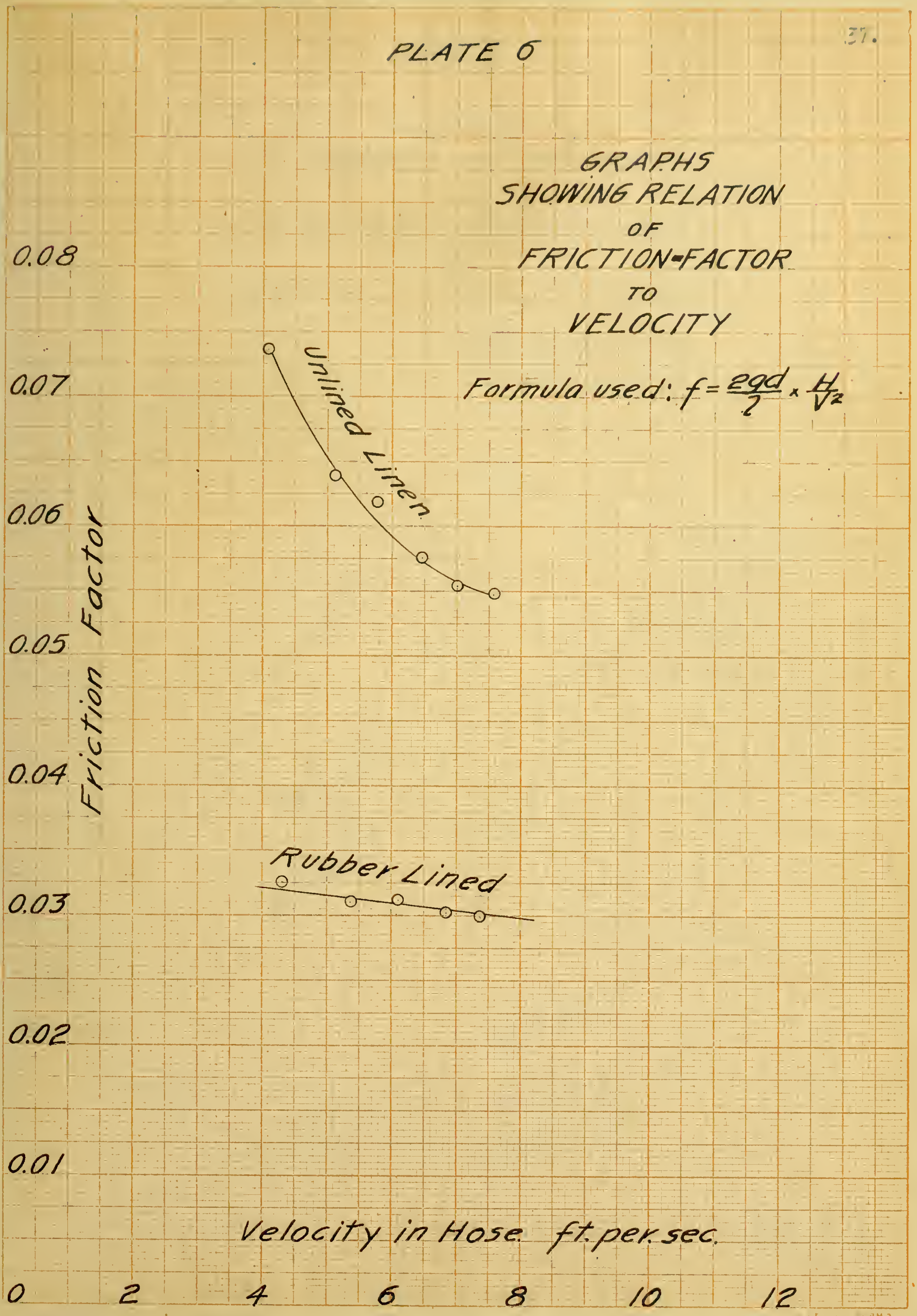


PLATE 6


GRAPHS
SHOWING RELATION
OF
FRICTION-FACTOR
TO
VELOCITY
Formula used: $f = \frac{2gd}{l} \times \frac{H}{V^2}$
Unlined Linen
Rubber Lined
Friction Factor
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Velocity in Hose ft. per sec.
0
2
4
6
8
10
12

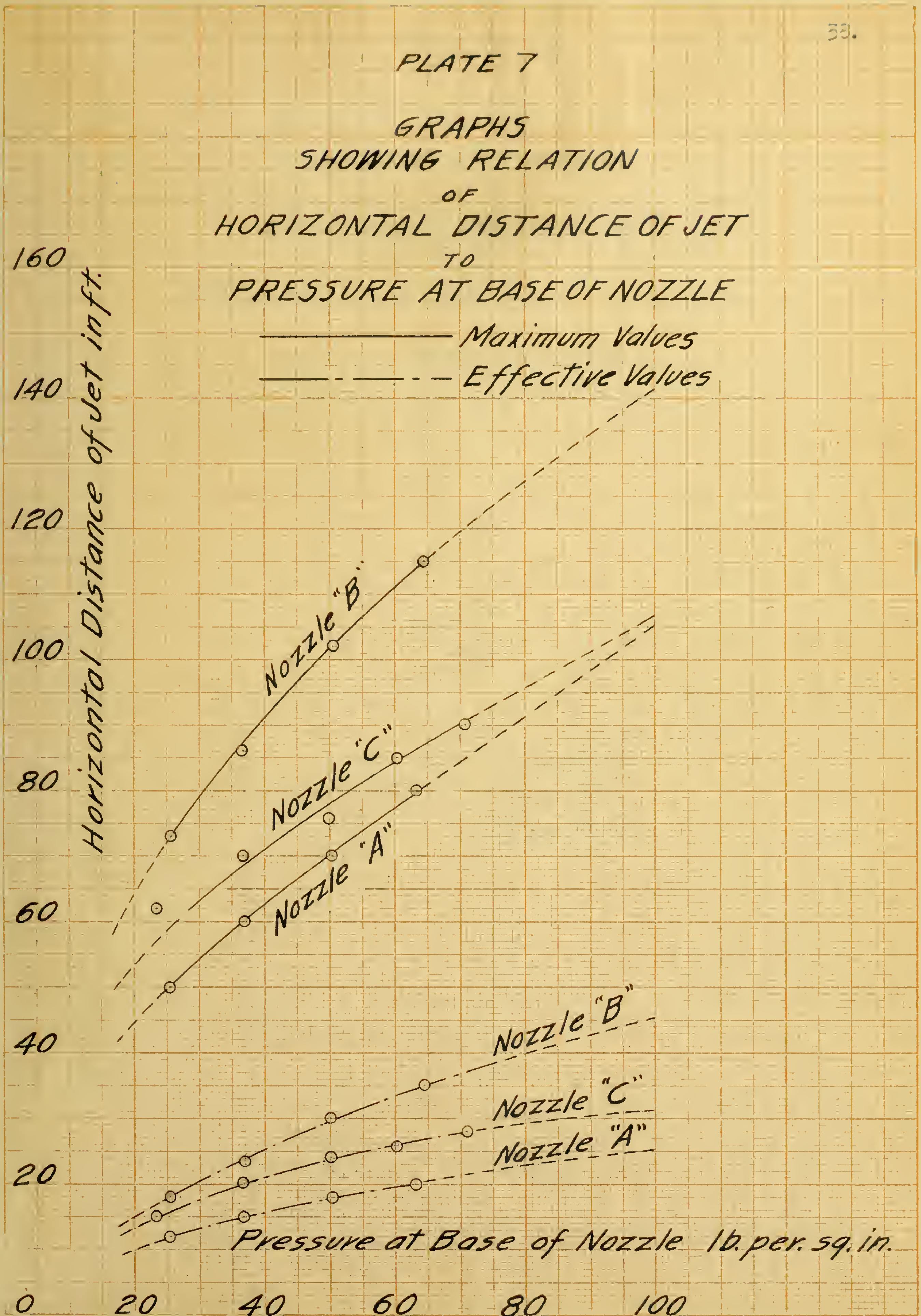


PLATE 7
GRAPHS
SHOWING RELATION
OF
HORIZONTAL DISTANCE OF JET
TO
PRESSURE AT BASE OF NOZZLE
Maximum Values
Effective Values
Horizontal Distance of Jet in ft.
160
140
120
100
80
60
40
20
0
Nozzle "B"
Nozzle "C"
Nozzle "A"
Nozzle "B"
Nozzle "C"
Nozzle "A"
Pressure at Base of Nozzle lb. per. sq. in.
20
40
60
80
100

PLATE 8

GRAPHS
SHOWING RELATION
OF
VERTICAL HEIGHT OF JET
TO
PRESSURE AT BASE OF NOZZLE